A Public Health Perspective on Distribution Systems

TCR/DS Stakeholder Workshop January 30, 2007

Stig Regli

OGWDW, USEPA

Overview

- The challenge of characterizing risks in the distribution system
- What does the waterborne disease outbreak information tell us?
- What do epidemiology studies tell us about endemic risk?
- Key points of NAS report
- Summary

The Challenge of Characterizing Risk in Distribution Systems

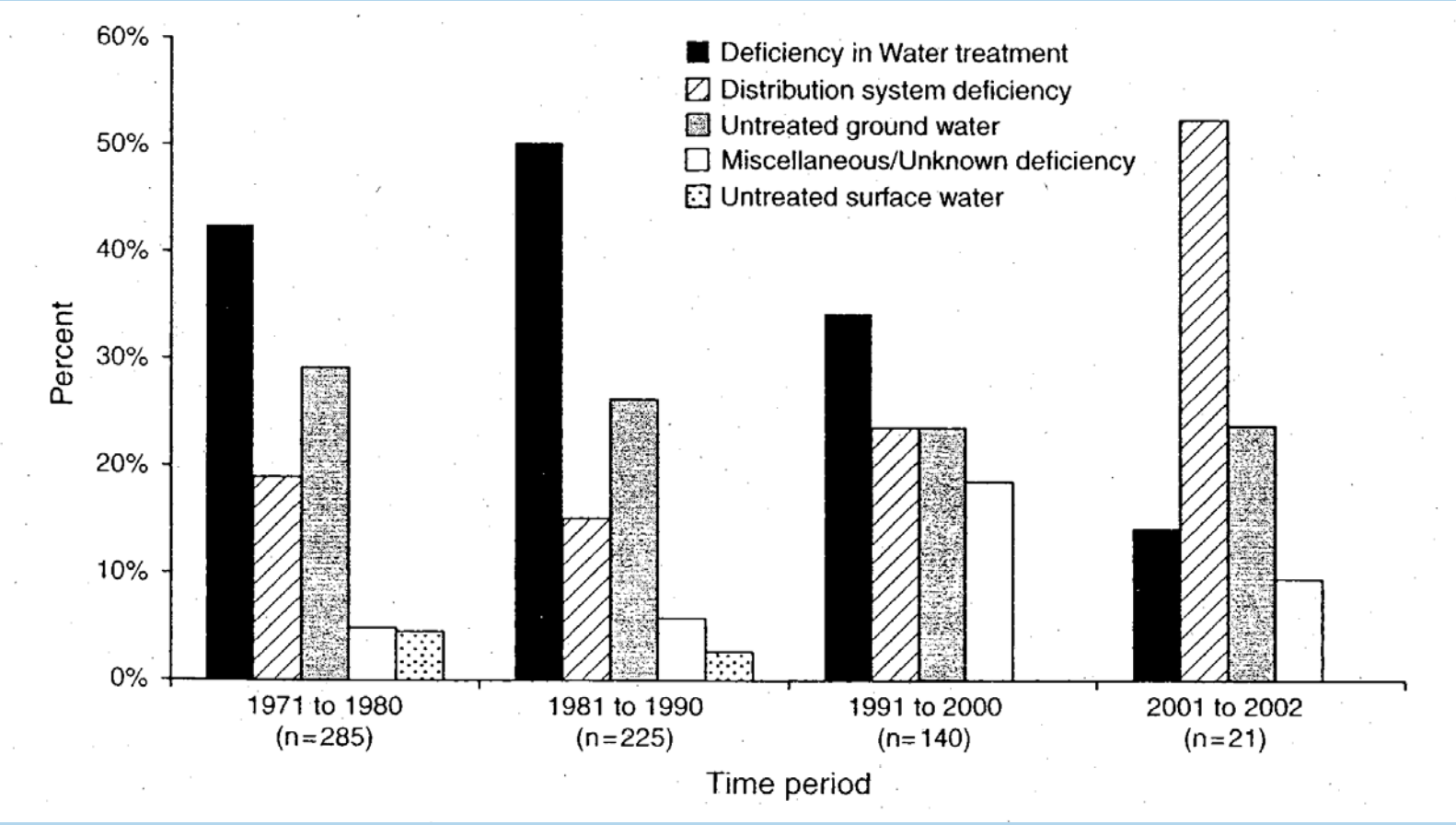
- Multiple pathways of contamination
  - Multiple entry points for each pathway per system
- Multiple contaminants of concern
  - Chemicals
  - Microbes (bacteria, viruses, protozoa)
- Intervention space (within water) between contaminant source and consumption taps ranges from nil to substantial
- Epidemiology data can be used to make general inferences
- Models relying on exposure and dose response relationships need to be developed in areas of greatest concern
  - Epidemiology data can help prioritize such areas

Analysis of Outbreak Data

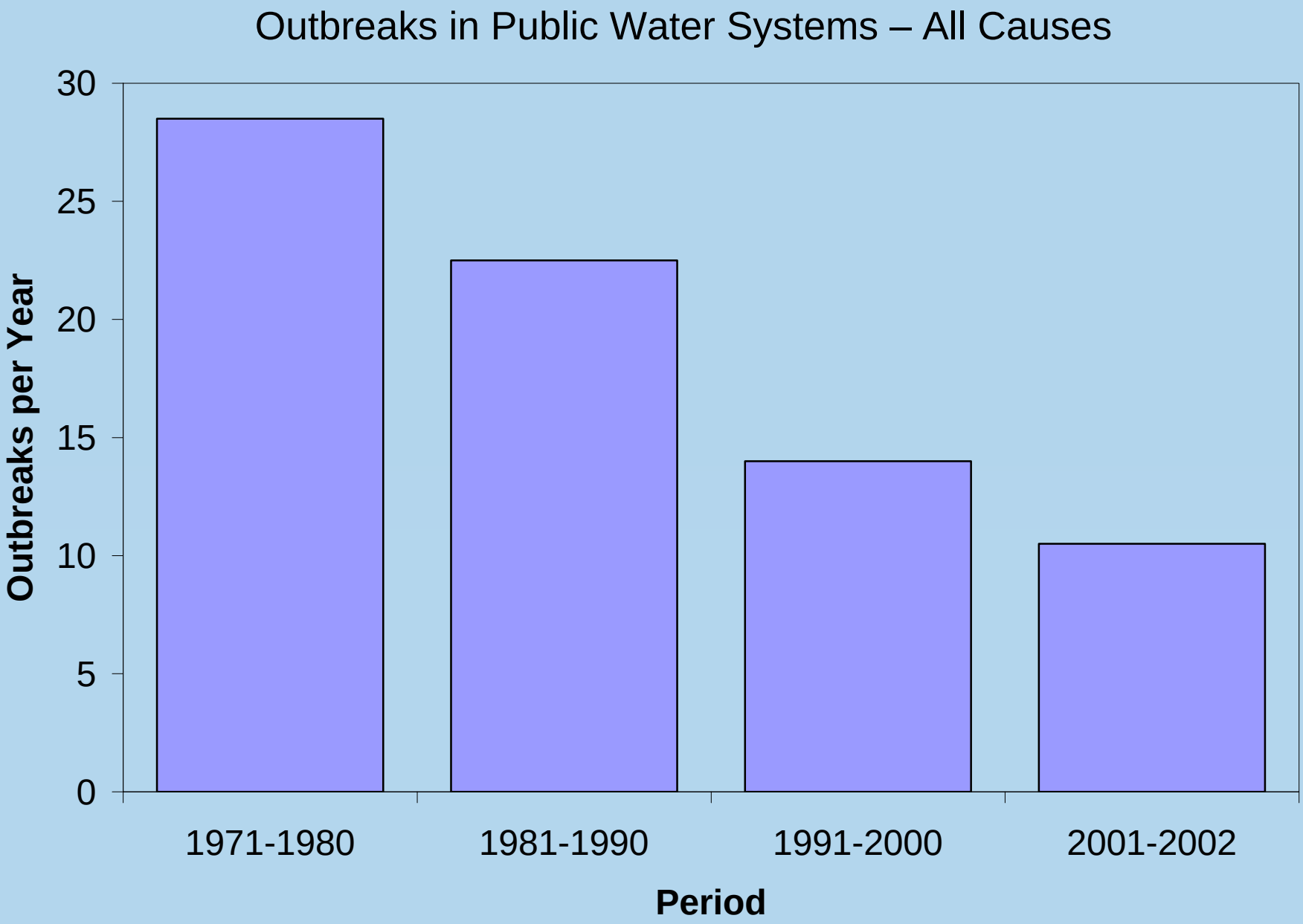
EPA's Historical Use of Outbreak Data in Regulation Development

- Informs relative importance of systemic causes for acute waterborne disease and potential opportunities for mitigation
  - Source/treatment vs. distribution system
  - Ground water vs. surface water
  - Lack of treatment or treatment failures
- Informs etiologic agents of concern
- Provides gross national indicator of relative magnitude of disease incidence from different causes but not actual national incidence
  - Only tip of iceberg indications

Trends in System Deficiencies in Public Water Systems



Craun, M.F. *et al*. 2006. Journal of Water and Health. *Waterborne outbreaks reported in the United States.* 04 Suppl 2: pp 19-30. Does not include Legionella.


Outbreaks in Public Water Systems – All Causes
Outbreaks per Year
30
25
20
15
10
5
0
1971-1980
1981-1990
1991-2000
2001-2002
Period

Key Observations of Trends

- Number of outbreaks due to all causes has dropped
- Number and percent of outbreaks due to treatment deficiencies has dropped
- Percent of outbreaks due to untreated GWs has remained about the same
  - Drop in numbers of outbreaks
- Percent of outbreaks due to DS contamination has increased
  - Not much change in number of outbreaks

Regulations Influencing Trends

- TCR (1989)
  - all public water systems
  - TC/FC/*E. coli* monitoring, MCLs
  - sanitary survey requirements for small systems
- SWTR (1989)
  - For SW or GWUDIS (ground water under direct influence of SW)
  - $\geq$ 3 & 4 log treatment for *Giardia* & viruses in source waters (turbidity and disinfection performance based monitoring)
  - Filtration avoidance criteria
  - $\geq$ 0.2 mg/l disinfectant residual at point of entry
  - Detectable residuals or HPC < 500/ml in > 95% of DS sites
- IESWTR(1998)
  - $\geq$ 2 log treatment for Cryptosporidium based on turbidity performance monitoring
  - sanitary surveys requirements for all SWs and GWUDIS

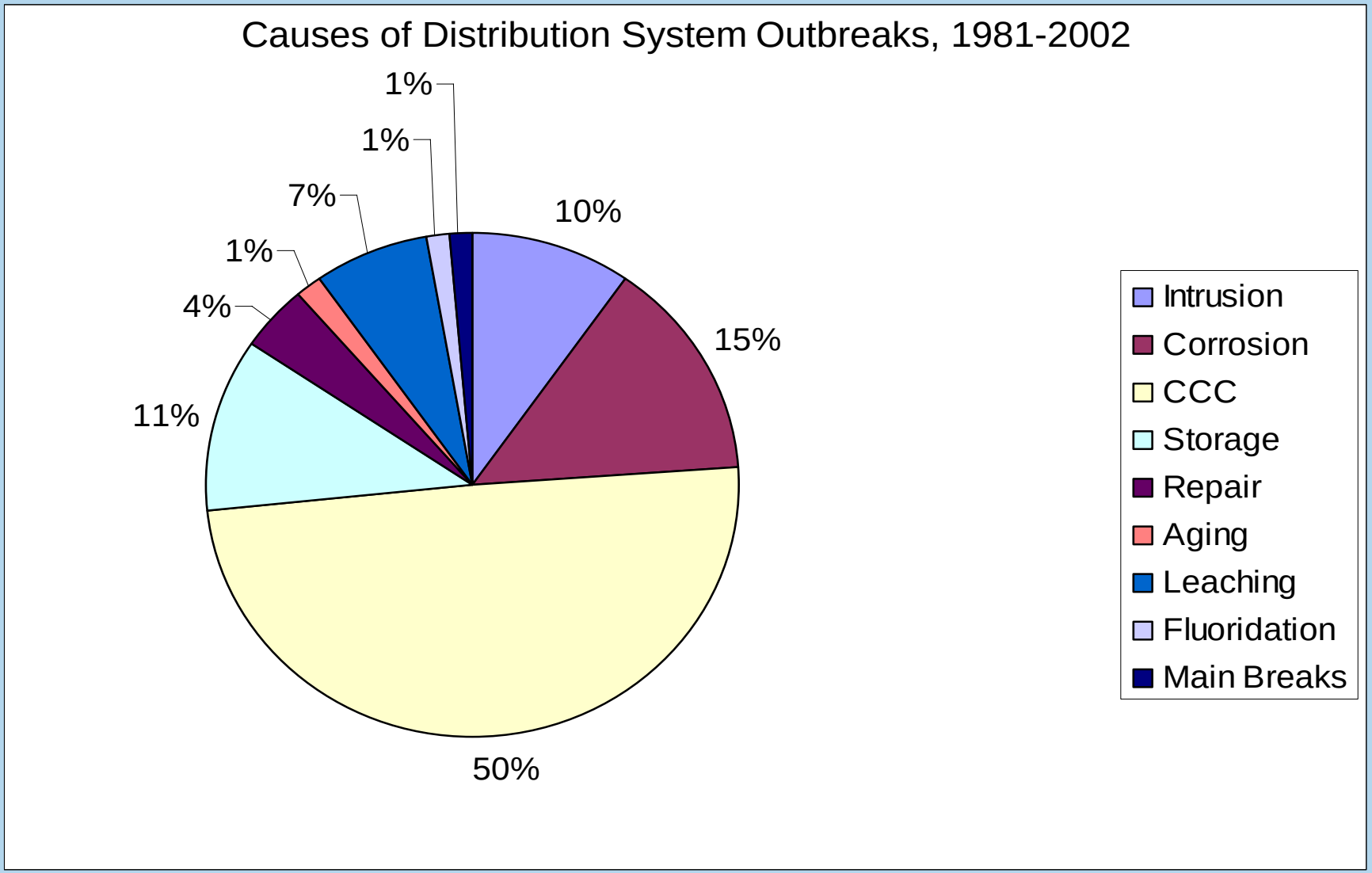
Other Influencing Factors

- Partnership program (AWWA, AMWA, NAWC, AWWARF, ASDWA, EPA,)
- Area Wide Optimization Program (States and EPA)
- Tighter and more frequent sanitary surveys by States

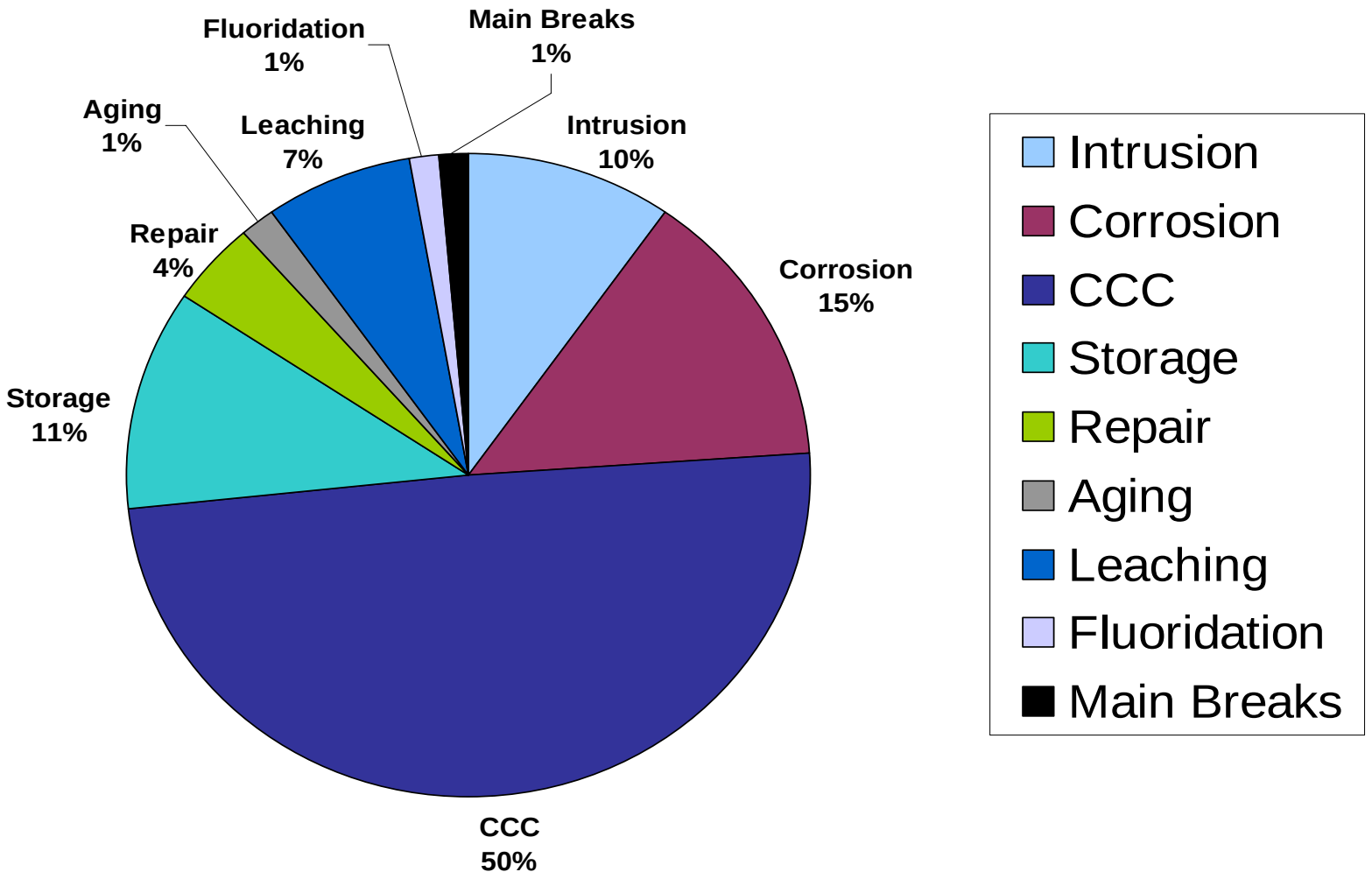
New Regulations That Will Further Influence Trends

- LT1 (2001) - mainly source/treatment
- LT2 (2005) - mainly source/treatment
- GWR (2006) – mainly source/treatment but some DS

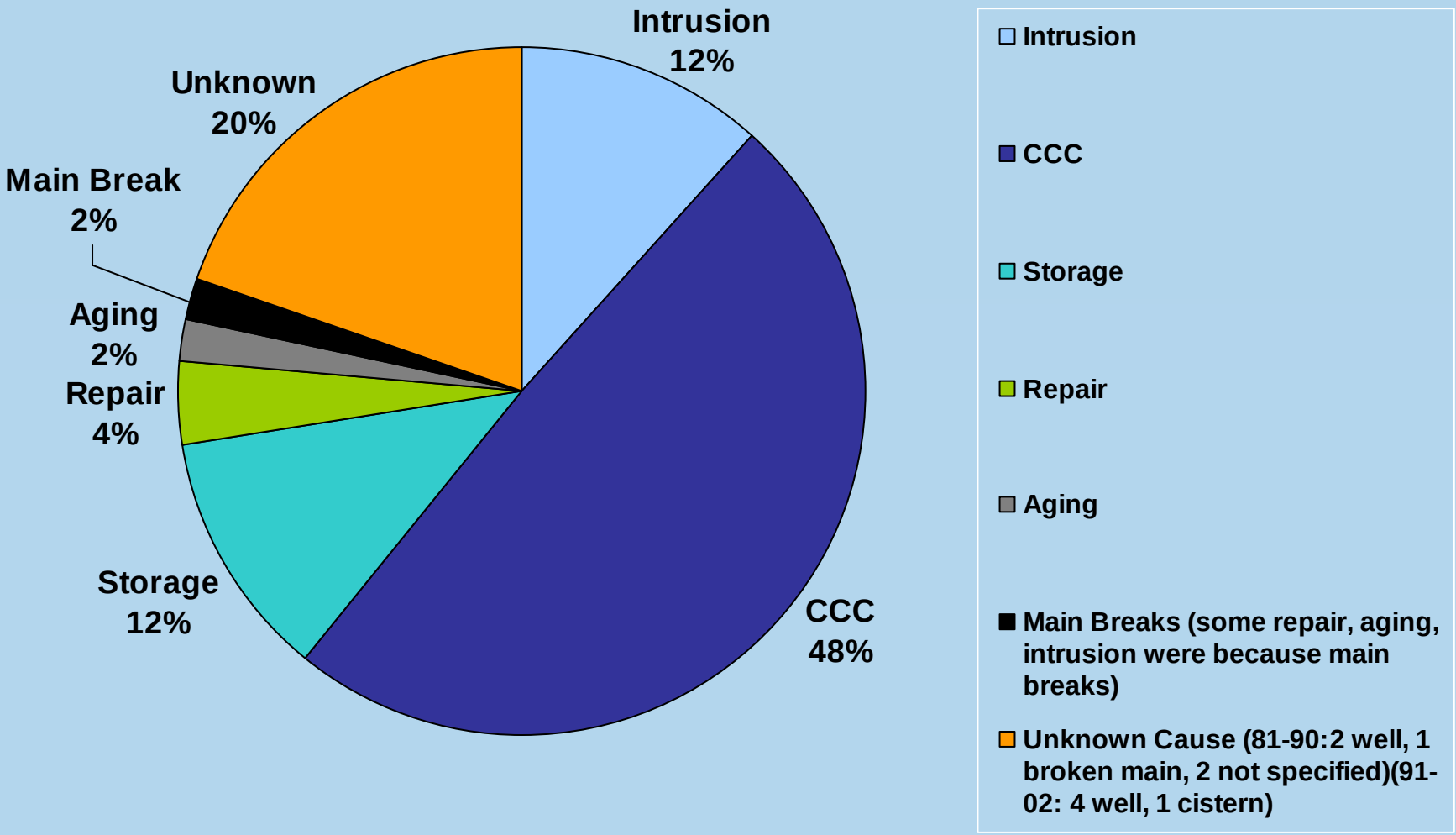
Cross-Connections and Backflow Exposure and Risks



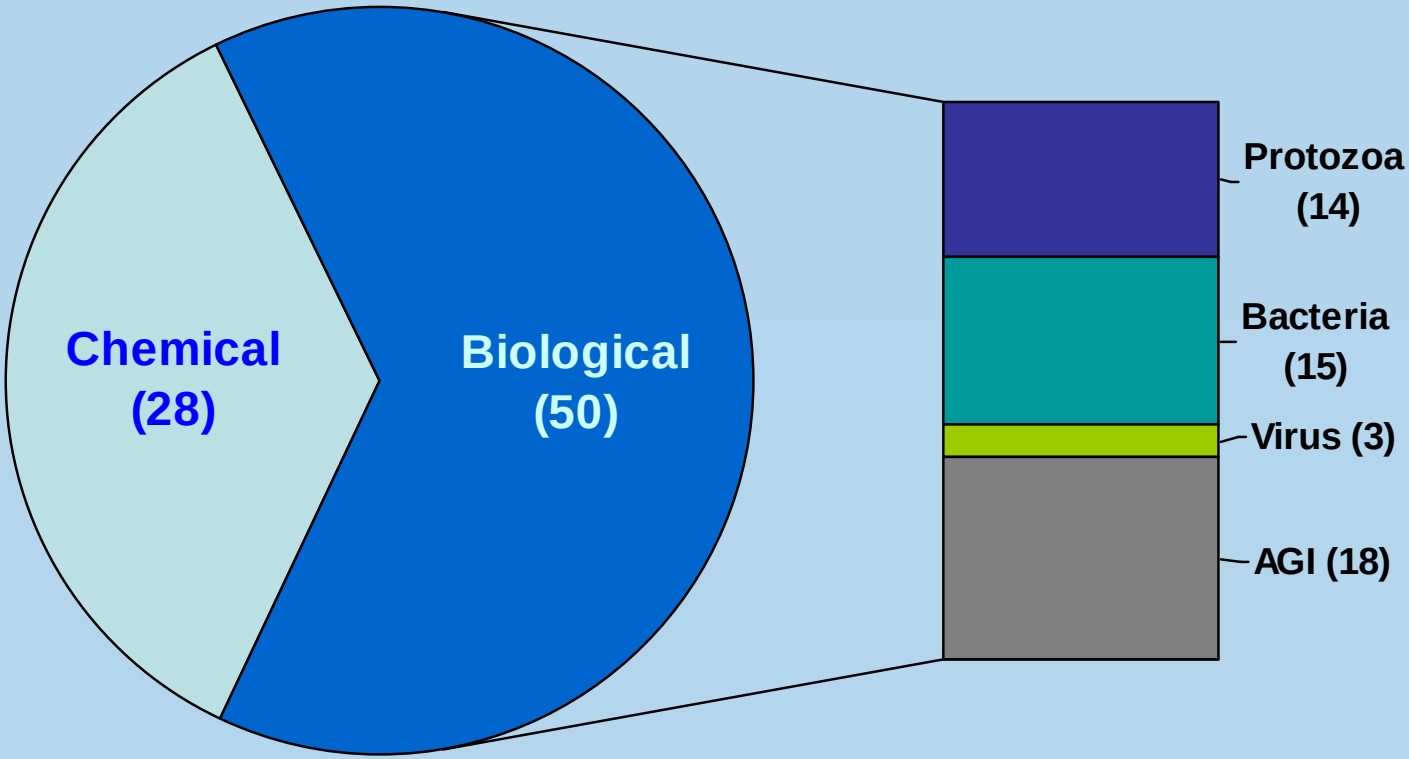
WBOBs Caused by Chemical and Biological Contamination, 1981 - 2002



WBOBs Caused by Biological contamination, 1981 - 2002

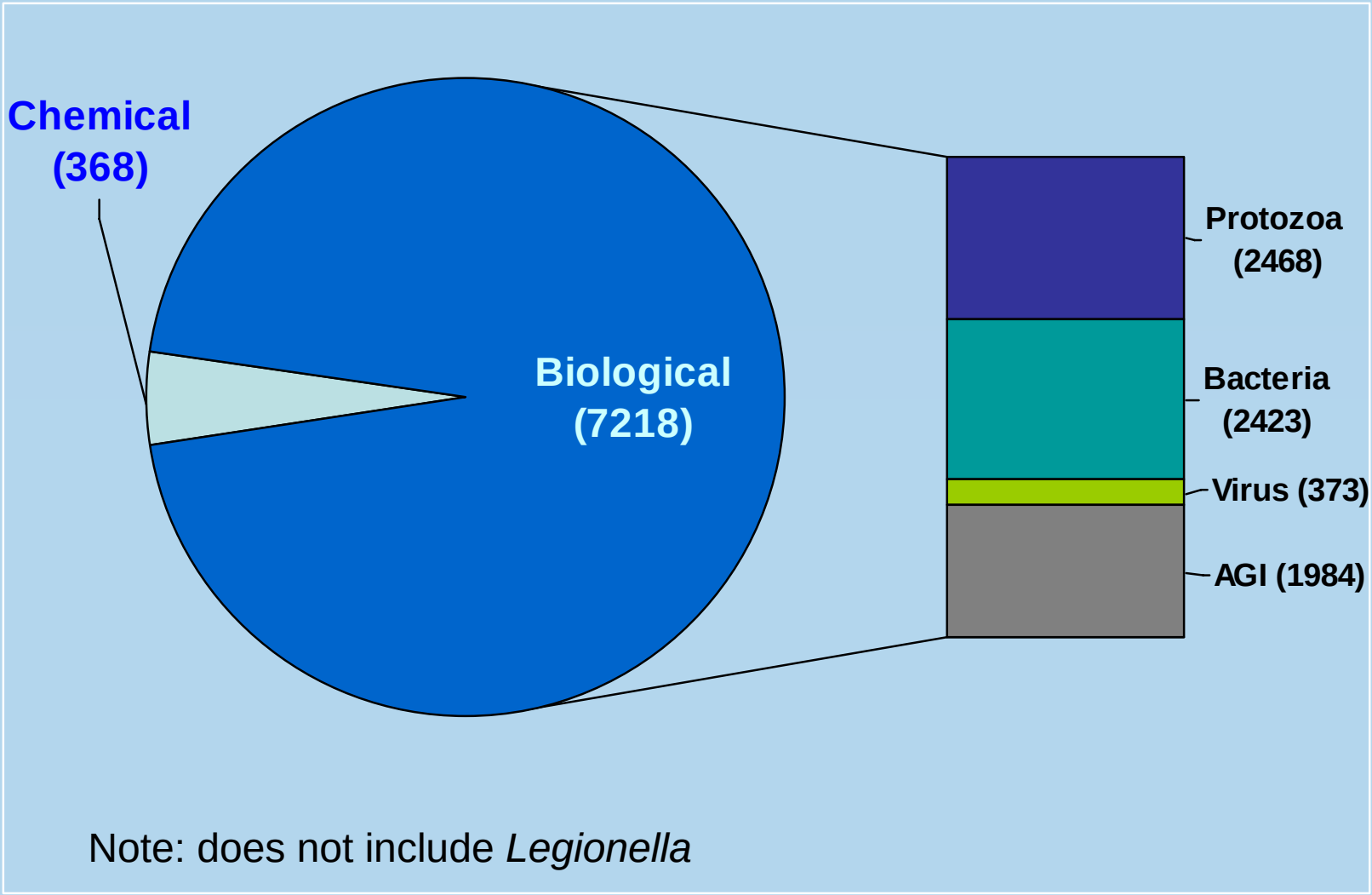


Chemical vs. Biological causes of Distribution System Outbreaks, 1981-2002



Note: does not include *Legionella*

Chemical vs. Biological Causes of Distribution System Illness Cases, 1981-2002



Note: does not include *Legionella*

Etiologic Agents, Illness, and DS Outbreak Summary Data; 1981-2002

Etiologic agent	No. of cases	No. of Outbreaks
Norwalk/SRSV	373	3
Vibrio cholerae	17	1
Campilobacter (jejuni)	513	4
Giardia spp. (lamblia/intestinalis)	2433	13
Salmonella spp.	1528	4
Cryptosporidium	5	1
*E. coli (*including O157:H7)	247	2
Shigella spp (sonnei)	118	4
AGI	1984	18
Chemicals	368	28

Note:*Legionella* not listed since only became part of CDC reporting beginning in 2001

12-22-06 CDC MMWR (Surveillance of WBDO 03 – 04)

- Initiated distinction of WBDOs being within or outside utility jurisdiction
- 51.5% of the drinking water deficiencies occurred outside the jurisdiction of water utilities
  - Majority of these WBDOs were associated with *Legionella* or chemicals/toxins
- Of the 17 WBDOs with known infectious etiology, eight [47.1%] were caused by *Legionella*
  - Reporting of *Legionella* started in 2001-2002 (8 outbreaks reported)
  - See appendix for implications on trend and etiology characterizations

What Does the Outbreak Data Tell Us?

- Percent WBDO due to DS causes is increasing
  - Little change in WBDO numbers due to DS causes
  - Distribution system outbreaks may be less recognized than source/treatment outbreaks because of smaller exposures
- Pathogens are more significant concern than chemicals
- Outbreaks due to cross connection contamination is largest contributor to DS outbreaks
- Substantial fraction of DS WBDOs occur outside of utility jurisdiction
  - *Legionella* appears to be biggest concern

Epidemiology Studies Informing Endemic Risk

Studies Considered

- Laval (2) - Payment et al (1991, 1997)
  - Detectable AGI levels attributed to DW in both studies
- Melborne – Hellard et al (2001)
  - Non-detectable AGI levels attributed to DW
- Davenport - Colford et al (2005)
  - Non-detectable AGI levels attributed to DW
- National estimate analysis (Messner et al 2006)
  - Used above studies and other information to inform national estimate
- UK – Hunter et al (2005)
  - Evaluation of risk factors associated with diarrhea

Unique Characteristics of Laval Studies

- Highly contaminated source water
- Treatment in first study probably met SWTR but not IESWTR
- Notable vulnerabilities to DS contamination
- Significant improvements in treatment but little change in DS conditions between studies
- Laval 1991 total attributable AGI incidence was 0.26 and Laval 1997 total was 0.08
  - i.e., 26/100 and 8/100 cases of AGI each year are attributed to DW from all causes of contamination

Estimate of Attributable Incidence of Acute Gastrointestinal Illness, cases per person-year (pre LT2, GWR)

Pathogen Source	Median Incidence	95% Credible Interval Lower	95% Credible Interval Upper
Source/Treatment (ST)	0.03	0.006	0.05
Distribution System (DS)	0.03	0.003	0.09
Total (ST+DS)	0.06	0.02	0.12

Pathogen Source	Mean National Attributable Cases	95% Credible Interval Lower	95% Credible Interval Upper
Source/Treatment (ST)	8 Million	1.6 Million	14 Million
Distribution System (DS)	8 Million	0.8 Million	25 Million
Total (ST+DS)	16 Million	5 Million	33 Million

Based on 273 million persons served by PWSs in the US.

From Messner, *et al.,* Developing a National Estimate of Waterborne Disease, *Journal of Water and Health*, Vol. 4, Supplement 2, 2006.

UK Study – Hunter et al 2005

- Case-control study in UK of risk factors associated with sporadic diarrhea; was not specifically designed to study waterborne disease.

- Results showed a very strong association between self-reported diarrhea and reported low water pressure at the home tap based on a postal survey of 423 subjects.

- Investigators suggested that the strength of the association between loss of water pressure and risk of diarrhea indicates that this was not a spurious association (Odds ratio of 12.5, 3.5 - 44.7, $p < 0.001$)

- Follow-up studies to confirm findings recommended by authors

Key Points From NAS Report

Trends Relevant to Deterioration of Distribution System Water

- Aging infrastructure (for most pipe types, the end of their expected life time is in the next 30 years)
- Decreasing number of reported waterborne disease outbreaks, but an increasing percentage attributable to distribution system issues
- Increasing use of bottled water and point-of-use treatment devices
- Increasing host susceptibility to infection and disease in the U.S. population
- Population shifts that have affected demand and lead to greater water residence times

Priorities for Mitigating Distribution System Contamination

- Backflow events through Cross Connections (H)
- Contamination during Installation and Repair (H)
- Maintenance of Storage Facilities (H)
- Premise Plumbing (H)
- Operator Training (H)
- Biofilm Growth (M)
- Loss of Residual via Water Age and Nitrification (M)
- Intrusion (M)
- Other Effects of Water Age (L)
- Other Effects of Nitrification (L)
- Permeation (L)
- Leaching (L)
- Control of Post Precipitation (L)

NAS Recommendations on National Approaches For Mitigating Risk

- EPA should work closely with stakeholders to establish the elements that constitute an acceptable cross-connection control program.

- Existing plumbing codes should be consolidated into one uniform national code.

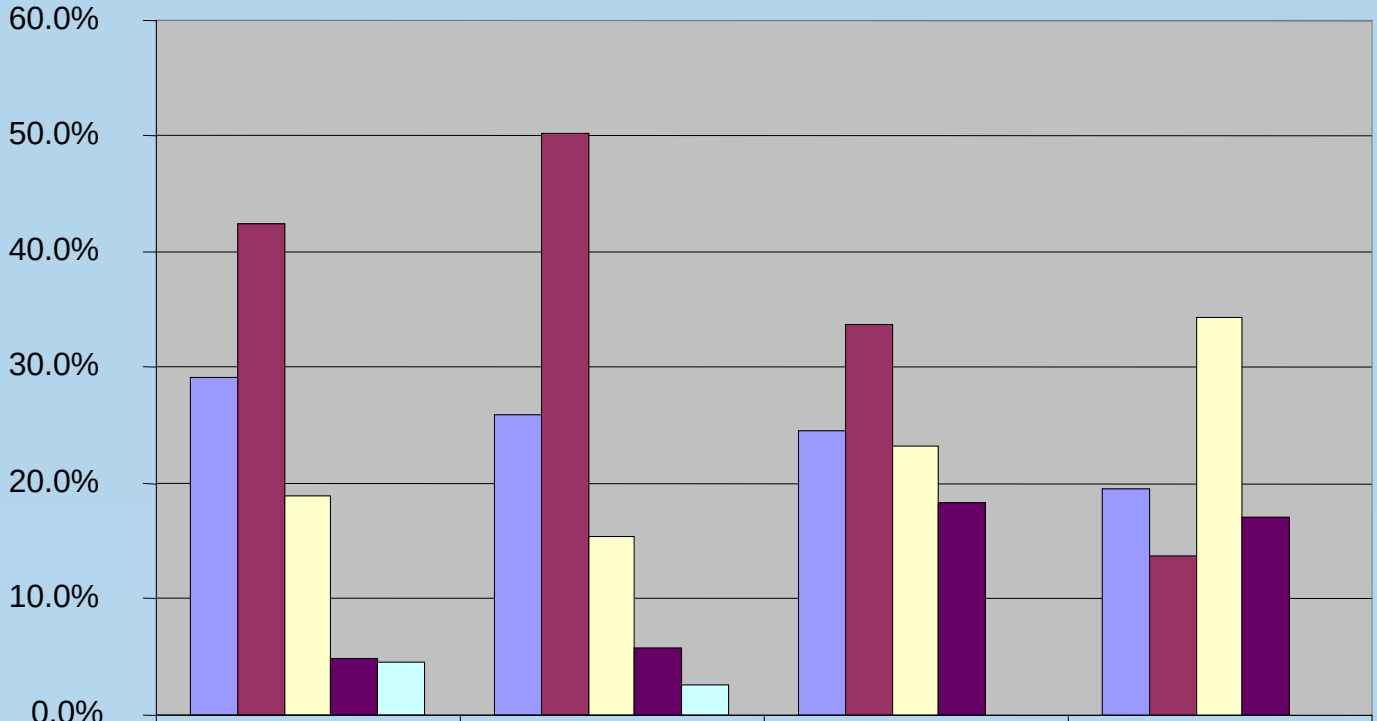
- For utilities that desire to operate beyond regulatory requirements, adoption of G200 or an equivalent program is recommended to help utilities develop distribution system management plans.

Summary of Health Risk Concerns

- Outbreaks
  - 79 distribution system outbreaks from 1981-2002, with 7,575 illness
    - Percent due to distribution system outbreaks has increased; percent due to source treatment have declined
  - Outbreaks are under-recognized and under-reported (tip of iceberg)
    - Distribution system outbreaks may be less recognized than source/treatment
- National Estimate of Risk From DS
  - 0.8 to 25 million cases of acute gastrointestinal illness per year may be caused by community water distribution system problems
- United Kingdom Study
  - Strong association between low tap pressure and self-reported diarrhea
  - Additional research needed to confirm
- NAS Report
  - Deterioration of water quality in distribution systems
    - Aging infrastructure, increasing main breaks and pipe replacements
  - The distribution system is the remaining component of public water supplies yet to be adequately addressed in national efforts to eradicate waterborne disease

Appendix

Trends in System Deficiencies for Outbreaks in Public Water Systems, 1971-2004 (not including *Legionella*)

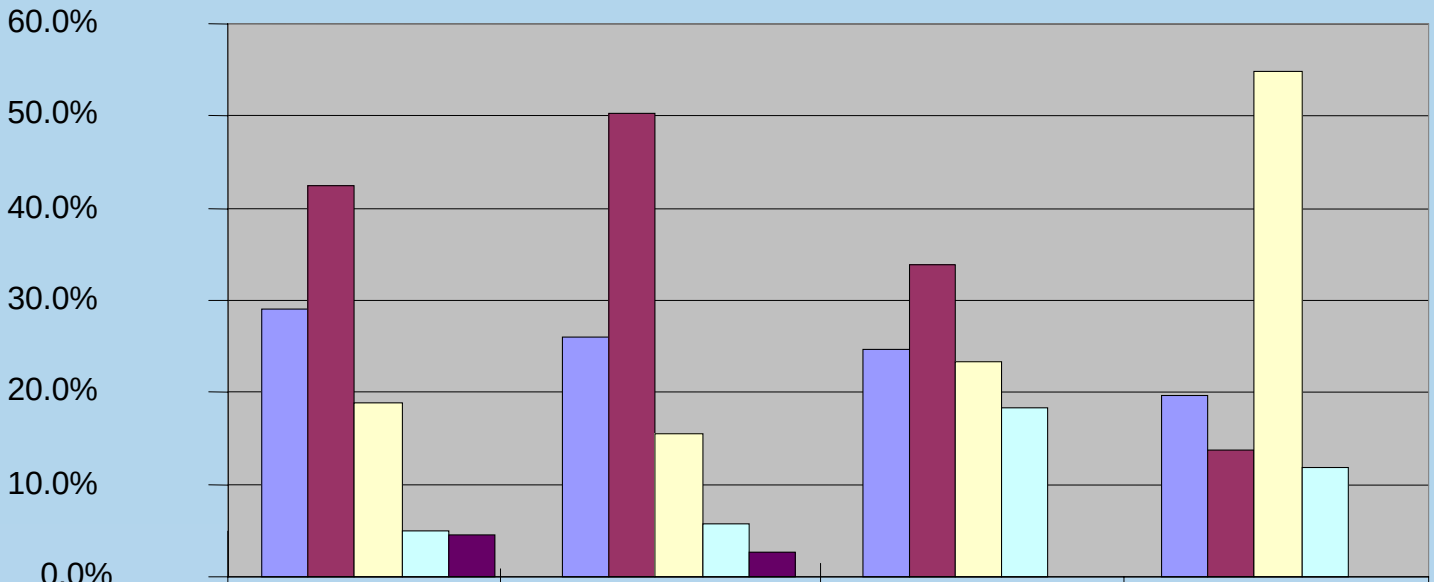


	1971 to 1980 (n=285)	1981 to 1990 (n=227)	1991 to 2000 (N=142)	2001 to 2004 (n=35)
untreated groundwater	29.1%	26.0%	24.6%	19.6%
water treatment deficiency	42.5%	50.2%	33.8%	13.7%
distribution system deficiency	18.9%	15.4%	23.2%	34.3%
miscellaneous or unknown	4.9%	5.7%	18.3%	17.1%
untreated surface water	4.6%	2.6%	0.0%	0.0%

Time Period

Source: Gunther Craun, 2007

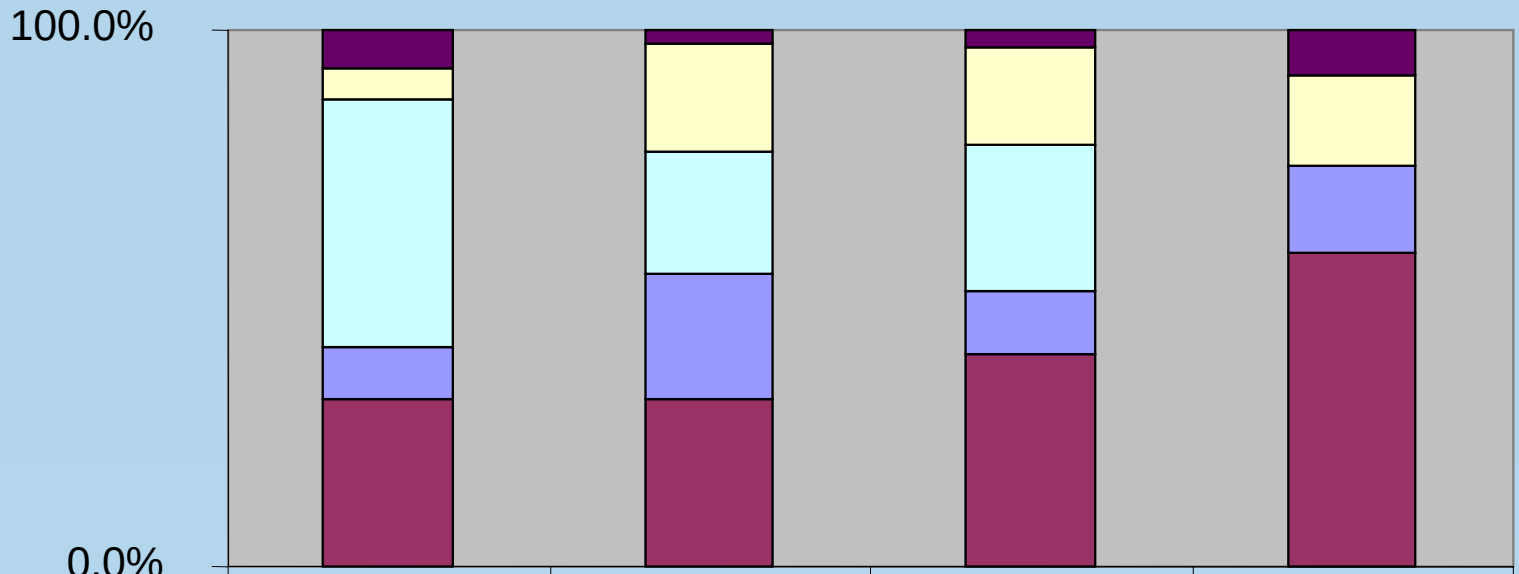
Trends in System Deficiencies for Outbreaks in Public Water Systems, 1971-2004 (with *Legionella*)



	1971 to 1980 n=285	1981 to 1990 n=227	1991 to 2000 n=142	2001 to 2004 n=51
untreated GW	29.1%	26.0%	24.6%	19.6%
water treatment deficiency	42.5%	50.2%	33.8%	13.7%
distribution system deficiency	18.9%	15.4%	23.2%	54.9%
Miscellaneous or Unknown	4.9%	5.7%	18.3%	11.8%
untreated SW	4.6%	2.6%	0.0%	0.0%

Source: Gunther Craun, 2007

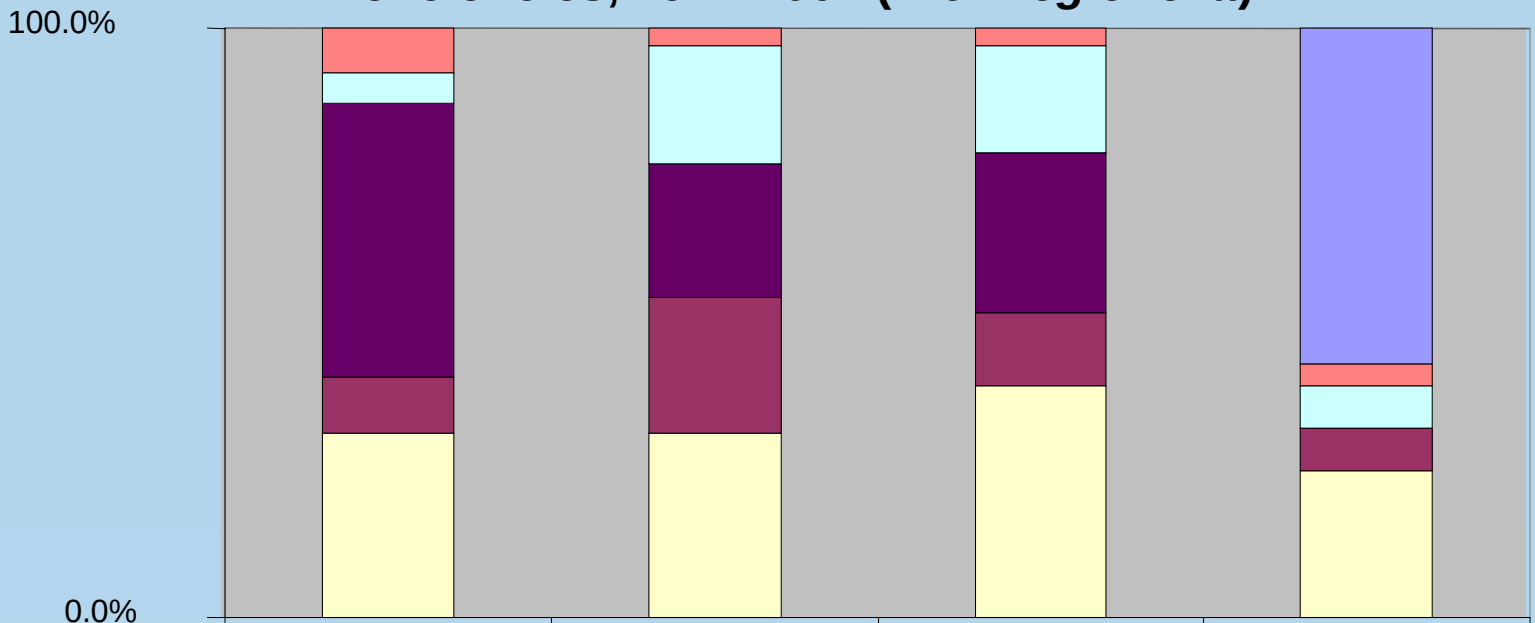
Etiologies of Outbreaks Caused by Distribution System Deficiencies, 1971-2004 (without Legionella)



	1971-80	1981-90	1991-2000	2001-2004
Virus	7.4%	2.9%	3.0%	8.3%
Protozoa	5.6%	20.0%	18.2%	16.7%
Unidentified Agent	46.3%	22.9%	27.3%	0.0%
Bacteria	9.3%	22.9%	12.1%	16.7%
Chemical	31.5%	31.4%	39.4%	58.3%

Source: Gunther Craun, 2007

Etiologies of Outbreaks Caused by Distribution System Deficiencies, 1971-2004 (with *Legionella*)



	1971-80	1981-90	1991-2000	2001-2004
Legionella	**0**	**0**	**0**	**57.1%**
Virus	7.4%	2.9%	3.0%	3.6%
Protozoa	5.6%	20.0%	18.2%	7.1%
Unidentified Agent	46.3%	22.9%	27.3%	0.0%
Other Bacteria	9.3%	22.9%	12.1%	7.1%
Chemical	31.5%	31.4%	39.4%	25.0%

Source: Gunther Craun, 2007

Key Assumptions in National Estimate Analysis

- Assume 2 to 5 log spread (95% interval) of incidence attributable to Source/Treatment
- Independently assume 2 to 5 log spread of incidence attributable to DS
- Laval 1991 total attributable incidence was 0.26 and Laval 1997 total was 0.08; we believe somewhere between 25% and 75% of the 0.08 (0.02 to 0.06) was due to DS contamination.
  - We assume the DS contribution was the same in both studies.
  - We assume the drop in attributable incidence between the two studies was due to improved treatment.
- Based on knowledge of DW systems in US and in the system studied, we assume that, in 1991,
  - Laval's source/treatment risk would rank between the 90^{th} to 99.5^{th} percentile of the US distribution of source/treatment risk and
  - Laval's DS risk would fall between the 50^{th} and 99^{th} percentile of the US distribution of DS risk.
- (units of attributable risk are cases per person-year)

National Estimate Model Approach

- Characterize distributional form for attributable AGI, as it varies from system to system and between source/treatment (ST) and distribution system (DS) causes.
  - Define a probability distribution to reflect uncertainty about the magnitude of this variability.

- Consider placement of studied system in the distribution, based on information on its source/treatment (ST) and distribution system (DS).
  - Define a probability distribution to represent uncertainty about these placements.

- Use data from two household intervention studies (Payment, *et al.*, 1991, 1993, 1997) to separately estimate the AGI incidence attributable to ST and DS in that system.
  - Probabilistically characterize uncertainty about what portion of the attributable incidence in Payment 1997 was due to ST vs. DS, assuming DS conditions were the same as in the earlier trial.

- Use numerical methods to derive national estimates and their uncertainties from the above information.